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A Summary of Fishery and Biological Data for Lingcod off the Southwest Coast of Vancouver Island

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A SUMMARY OF FISHERY AND BIOLOGICAL DATA FOR LINGCOD OFF THE SOUTHWEST COAST OF VANCOUVER ISLAND

by

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ABSTRACT

Cass, A. J., L. J. Richards, and J. T. Schnute. 1988. A summary of fishery and biological data for lingcod off the southwest coast of Vancouver Island. Can. Tech. Rep. Fish. Aquat. Sci. 1618: 33p.

Data used for stock assessments are often compiled from a variety of sources. This report provides detailed documentation of data sources for a size-structured population model used to assess an exploited lingcod (Ophiodon elongatus) stock. The main data files and programs that are compiled for model input are available to interested readers on a diskette. We chose to consider the lingcod stock off the southwest coast of Vancouver Island (PMFC Major Area 3C) over the time period 1956-86. Catch and effort data from the commercial lingcod fishery are compiled from four main sources and are combined in the analysis with information from biological samples of the commercial catch.

RÉSUMÉ

Cass, A. J., L. J. Richards, and J. T. Schnute. 1988. A summary of fishery and biological data for lingcod off the southwest coast of Vancouver Island. Can. Tech. Rep. Fish. Aquat. Sci. 1618: 33p.

Les données dont on se sert pour évaluer les stocks sont souvent compilées à partir de diverses sources. Le présent rapport fournit une documentation détaillée des sources de données pour un modèle de population structurée en fonction de la taille qui a servi à evaluer un stock exploité de morue-lingue (Ophiodon elongatus). Les principaux fichiers de données et programmes qui sont compilés pour l'établissement du modèle sont disponibles sur disquette pour les lecteurs intéressés. Nous avons choisi d'examiner le stock de morue-lingue au large de la côte sud-ouest de l'ile de Vancouver (zone principale 3C de la CPMP) au cours de la période de 1956 à 1986. Les auteurs compliment les données sur les prises et sur l'effort de pêche commerciale de la morue-lingue à partir de quatre sources principales et les combinent dans l'analyse avec les informations obtenues des échantillons biologiques des prises commerciales.

INTRODUCTION

This report documents fishery and biological data used in a model of an exploited lingcod (Ophiodon elongatus) stock off the southwest coast of Vancouver Island. The analysis is presented in the primary publications of Schnute et al. (1988a; 1988b) and is based on the model of Schnute (1987) for a size-structured population. The data used in the model were compiled from several sources according to complex selection criteria. The aim of this report is to provide more detailed documentation of the data than is possible in the framework of a primary publication. Most of the data files and computer programs referenced in this report are available to interested readers on diskette.

The report is divided into four main parts. The first part describes the compilation of catch and effort data used in the analysis. The second part describes the biological data. The third part describes how the fishery and biological data were combined into the format required by the model. The fourth part details the actual computer programs, calculations and file handling procedures. Summaries of the computer files on diskette are given in the appendices.

FISHERY DATA

DATA SOURCES

Lingcod stocks off southwest Vancouver Island are exploited by trawl and by hook and line fisheries. There have also been unknown, and presumably small, catches by Indian food fisheries, recreational fisheries and foreign national (other than United States) fisheries. The commercial trawl fishery accounts for the majority of the lingcod catch. This is a multispecies fishery that also targets on Pacific cod (Gadus macrocephalus), petrale sole (Eopsetta jordani), and occasionally other species. Catches of Pacific cod and petrale sole have been restricted by quotas and/or trip limits at various times in the history of the trawl fishery. There have been no legal restrictions on the lingcod catch, except for occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit, in 1942. Lingcod catches have been limited in the past by low market demand. Here, we use the term catch to refer to landed catch, recognizing that discards may have occurred at sea.

Beginning in 1956, catch statistics of Canadian and United States commercial fishing vessels have been compiled annually by statistical area. Here, we restrict our analysis to the region off southwest Vancouver Island known as the Canadian portion of Pacific Marine Fisheries Commission (PMFC)

Major Area 3C (Fig.1) and to the time period 1956-86. The Canadian portion is hereafter called Area 3C-N. The United States portion is called Area 3C-S. Area 3C-N includes Canadian minor statistical areas 21, 23 and 24, although in recent years the boundaries have been revised. For example, based on the 1985 revision, Area 3C-N includes minor statistical areas 21, 23, 24, 121, 123, 124-1 to 124-3, and 125-6.

The compilation of catch statistics for Area 3C is somewhat complex, as illustrated by Table 1. Between 1963-86, we chose to include catches from Area 3C-N only in the analysis. However, between 1956-62, Washington Department of Fisheries did not report catches by Washington State minor area and it was not possible to determine the Area 3C-S component of the United States trawl catch. We were forced to use the total Area 3C catch for the analysis. The United States lingcod catch from Area 3C-S between 1963-74 was small (less than 100 t annually) (Westrheim and Pedersen 1986). If that trend had applied to the period 1956-62, then the effect of including the Area 3C-S catch is minor.

PMFC reports, published annually, present the combined Area 3C lingcod catch by Canadian and United States trawl vessels. In order to determine the United States trawl component to the Area 3C catch, it is necessary to subtract the Canadian trawl catch from the PMFC figures. These derived catches are somewhat approximate, as the Canadian catch may have been updated after the PMFC figures were compiled. For this reason, PMFC figures are used to represent the total trawl catch between 1956-80. The last reported catches of lingcod from Area 3C-N by United States vessels occurred in 1980, as a result of extended jurisdiction.

We used two sources of data to construct the annual time series of Canadian catch and catch per unit effort (CPUE) for Area 3C-N lingcod. These were (a) the annual British Columbia catch statistics published by the Economics and Statistics Branch of the Department of Fisheries and Oceans, and (b) the Groundfish data base maintained by the Groundfish Section of the Biological Sciences Branch, Department of Fisheries and Oceans. The British Columbia catch statistics were used to determine the annual Canadian lingcod catch from Area 3C-N for gear types other than trawl. The Groundfish data base was used to determine the Canadian Area 3C-N trawl catch and CPUE. Fishing effort was obtained by extrapolating CPUE to the total Area 3C-N catch.

The Groundfish data base is maintained on a Vax 11/785 computer at the Pacific Biological Station in Nanaimo (Leaman and Hamer 1985). It contains information from interviews of a subsample of trawl vessel skippers and sales records of uninterviewed landings. Data are recorded by port samplers at the end of a fishing trip and include location of fishing, depth, hours fished and weight of the catch by species. The combination of interviewed landings and sales records is the best information available for the Canadian lingcod catch by trawl. The data base also includes a vessel file with supplementary data on horsepower and gear type.

DATA SELECTION AND COMPILATION

As most of the Area 3C-N landings were by trawl gear, and as the trawl data are the most complete, trawl data only were used to estimate CPUE. Prior to estimating CPUE however, it was first necessary to determine which trawl records to include in the analysis. Trawl records were selected on the basis of several criteria including month of fishing, locality, trawl gear type and species composition of the catch (Table 2). Selection by species composition was necessary to account for effort targeted at species other than lingcod, even though lingcod may have been a component of the catch.

We selected records for the May-September fishing period only. This was for two reasons. First, the trawl fishery is highly seasonal. Between 1956-86, 91% of the Canadian lingcod catch occurred during the May-September period. Second, biological samples from other times of the year are predominately female. It appears that male lingcod become unavailable to trawl gear between October-April. Between May-September, male and female lingcod are nearly equally represented in the catch.

We also selected records on the basis of gear type. Since the 1950s the trawl fishery has evolved from vessels using gear suspended from a single cable, termed single gear, to vessels using gear suspended from a double cable, termed double gear. We selected records from those vessels using the more common double gear fishing method only.

The way in which effort is assumed to be partitioned among different species in a multispecies fishery will affect the calculation of CPUE. As we had no prior information on which method resulted in the best index of stock abundance, we chose to select three methods of effort qualification. For the first method, termed 0%, the analysis included the lingcod catch and total trawl effort from all records that reported a lingcod catch. For the second method, termed 25%, the analysis included the lingcod catch and total trawl effort from a record only if lingcod account for 25% or more of the catch by weight reported on the record.

The third method used to qualify effort was the Option-2 method (Westrheim 1983). For this method, lingcod catch and total effort for a time period are summed over specified depth strata. Records from the two depth strata with the highest lingcod catches only are included in the analysis, and all trawl effort within these two strata is assigned to lingcod. Following Westrheim (1983) we chose 10-fa depth strata, in the range 10-109 fa, and repeated the analysis for two time periods within each year. We chose to compile the catch and effort data separately for the May-June and July-September periods, to allow for seasonal changes in lingcod depth distribution. Because depth distributions tend to be area specific, we further restricted the analysis to records from the Big Bank fishing ground. Big Bank accounted for 71% of the all-year, interviewed lingcod catch between 1956-86. The selected depth intervals were mostly in the range 30-59 fa (Table 3).

In addition to qualifying effort according to the species catch, we also standardized for variation in vessel fishing power by the method of Westrheim and Foucher (1985). In this method, the effort recorded from each selected trawl landing is adjusted by the relative fishing power of the vessel making the landing, as determined by its horsepower class. We applied the relative fishing power coefficients published in Table 8 of Westrheim and Foucher (1985) to all selected trawl landings between 1956-86. The published coefficients are based on the combined catch and effort at the 80% qualification level of Area 3C-N Pacific cod, petrale sole and lingcod between April-September 1960-81. Although we have extrapolated the series to a wider time horizon, there have been no major changes in vessel type since 1981.

BIOLOGICAL DATA

Biological samples from the commercial trawl fishery for Area 3C-N lingcod have been collected annually since 1956 (Table 4). The samples provide information on the length distribution, sex composition and more recently the age composition of lingcod in catches from known locations, depths of fishing and dates. Beginning in 1977, dorsal fin rays were collected for routine age determination (Beamish and Chilton 1977) as part of the biological sampling program. The fin-ray method as applied to Area 3C-N lingcod has been partially validated through tagging studies of oxytetracycline-injected fish (Cass and Beamish 1983).

Biological samples from the commercial fishery were collected at the port of landing. Lingcod length measurements were made at three different processing stages. These were round (whole fish), dressed head off, and frames (filleted fish). Fork length is measured from the tip of the snout to the fork in the tail. Dressed length, used for the dressed head off stage, is measured from the origin of the first dorsal fin to the fork in the tail. All measurements were by 1-cm length intervals. During the 1956-75 period most lingcod were measured for dressed length without recording the sex, as lingcod were usually dressed and headed at sea.

Because catch is recorded by weight, we converted all length measurements into weight for consistency in the analysis. Fork length FL (cm), dressed length DL (cm), and weight WT (kg) are related by the following rules:

(1) $FL = -1.8+1.258*DL,$

(2) $WT = 3.488*10^{-6}*FL^{3.246}.$

Relationship (1) between fork length and dressed length is from Wendler (1953). The length-weight relationship (2) was derived from the data described in Cass et. al (1986), by combining male and female lingcod samples. The samples were collected by trawl from Area 3C-N during a research cruise in

August 1985. Although other length-weight relationships are available for lingcod, we considered the relationship above to be most representative of our biological samples. The weight data are used to provide a size distribution of the exploited population for each year in the model as well as an estimate of growth. All analyses of biological samples are based on collections from Area 3C-N between May-September only.

We estimated model growth parameters with two methods. The first method was based on the von Bertalanffy relationship between age a and weight w

$$(3) \qquad w = w_{\infty}(1 - e^{-k(a-a_0)})$$

where w_{∞}, k, a_0, are model parameters. The second method was based on a Ford-Walford relationship between the weight w and the subsequent weight w' one year later:

$$(4) \qquad w' = W + rho*w.$$

As described by Schnute (1985), the parameters in (4) are related to those in (3) by

$$(5a) \qquad W = w_{\infty}(1 - e^{-k}),$$

$$(5b) \qquad rho = e^{-k}.$$

Data for (3) come from aged biological samples, where length was first converted to weight for each sample for which age estimates were available (Table 5). Von Bertalanffy growth parameters were then estimated by the simplex search method (Mittertreiner and Schnute 1985) using least squares as the criterion of the fit. Data for (4) come from a tag-recapture study in Area 3C-N initiated in 1982 (Cass et. al. 1983). In order to estimate growth in one year, length was again first converted to weight. We then regressed the 1983 recapture weight against the 1982 release weight. Our regression allowed for error in both release and recovery weights, as described in Schnute et al. (1988a). The parameters estimated in (3) and (4) proved to be comparable, given the theoretical relationship (5).

Different growth parameters apply to male and female lingcod, as female lingcod have a faster growth rate. As our purpose was to define the growth of a typical exploited population, we combined samples from male and female lingcod in proportion to sample sizes in the catch. Similarly, age-weight samples were combined across years without regard to possible among-year differences in growth.

COMPILATION OF FISHERY AND BIOLOGICAL DATA

As described by Schnute (1987)and Schnute et al. (1988a, 1988b), model analysis begins by compilation of the catch and effort data into various

weight classes. A weight V is defined at which full recruitment occurs to the fishery. By the model's growth law (4) a fish of weight V grows to weight

(6) $V' = W + rho*V$

in one year. Pre-recruits are defined by weights less than V, new recruits by the weight interval [V,V'), and the previously exploited population by weights of V' and greater. The total recruited population is defined by weights of V and greater.

To estimate V for Area 3C-N lingcod, we combined all lingcod weight data from 1956-86 and plotted the weight distribution (Fig. 2). By visual inspection, we chose 2.25 kg as the weight at recruitment, V. This was the smallest weight at which a significant portion of the catch occurred. We applied the growth law to determine V', and then divided the catch into pre-recruits and total recruited components for each year, based on the weight distribution. CPUE was calculated from the total recruited catch for each of the qualification levels (0%, 25% and Option-2). CPUE was further divided into a component due to new recruits and a component due to the previously exploited population, again based on the weight distribution. The weight distribution was also used to calculate mean lingcod weight, square root of the mean square residual weight, cube root of the mean cube residual weight and fourth root of the mean fourth power residual weight for the newly recruited, previously exploited, and total recruited population components.

STRUCTURE OF COMPUTER FILES

The sequence of data compilation and analysis is summarized as flow diagrams in Fig. 3-5 for the fishery, biological, and joint data sets, respectively. Analysis of the fishery data began with the Groundfish data base and with miscellaneous published reports of catch data (Fig. 3). A general use program called GFSEL has been developed to access the Groundfish data base (Leaman and Hamer 1985). We constructed six GFSEL command files (Table 2) to retrieve trawl catch and effort data for Area 3C-N lingcod according to the selection criteria described above. The first command file (GFSEL.COM) retrieved the annual Canadian trawl landings of lingcod from Area 3C-N. The remaining command files retrieved the interviewed trawl catch and effort data used to calculate CPUE.

There was one GFSEL command file for each of the 0% (GFSEL0.COM) and 25% (GFSEL25.COM) qualification methods, and three files (GMAYJUN.COM, GJULSEP.COM, and GOPT2.COM) for the Option-2 method. The Option-2 method was more complex because it required initial data selection by GFSEL for each time period (see Figure 3, Box A). The intermediate report files generated by GFSEL (GMAYJUN.AUD, GJULSEP.AUD) were then inspected to determine which depth strata to include in the analysis (Table 3). The final command file

(GOPT2.COM) retrieved the catch and effort data for the selected depth intervals in each period from the Groundfish data base.

The raw data files produced by GFSEL for each qualification method (RTR0.DAT, RTR25.DAT, and RTR02.DAT) contained all GFSEL records that met the selection criteria. We used a FORTRAN program (SUM.FOR) to read each raw data file, merge the vessel codes with the vessel data base, perform the vessel fishing power standardization, and produce summary CPUE files (CPUE0.DAT, CPUE25.DAT, and CPUE02.DAT). For these summary CPUE files, a record consisted of year, trawl catch and trawl effort, according to the qualification method.

The raw data file from GFSEL with all lingcod Area 3C-N trawl catch records (RCANTRT.DAT) was also summarized by SUM.FOR. This produced a trawl catch file (CANTRAWL.DAT) with records consisting of year and total Canadian trawl lingcod catch. The trawl catch file was edited to include the PMFC trawl catch for 1956-80, and the Canadian line catch. The final catch file (CATCH.DAT) was then merged with the three summary CPUE files to produce the final catch/effort file (CAEFF.DAT, Table 6). This file was transferred to an IBM-compatible PC.

Biological data were stored on magnetic tape at the Pacific Biological Station in a series of files that we have collectively termed Groundfish biological data. The files vary in content and format among years. Since 1977, for example, each biological sample is recorded in a separate file. We began the biological data analysis by compiling the biological data into five summary files (Fig. 4). There were two files of length-frequency data from samples collected between May and September 1956-77 (LENGTH1.DAT) and between May and September 1978-86 (LENGTH2.DAT). These two files were merged into one file (LENGTH.DAT) for the analysis (Table 4). The age file (AGELT.DAT) contained the age and length data for the subset of samples in the length file for which age determinations were completed by the fin-ray method. These samples covered the period 1977-85 (Table 5). The age file has a format that is typical of all biological data files over the 1977-86 period. The length-weight file (LENWT.DAT) contained the 1985 cruise data used to estimate the length-weight relationship. The tagging data file (TAG.DAT) contained the tagging study data for lengths at release in 1982 for lingcod recaptured in 1983. The length-weight data were used to determine the length-weight relationships only. These estimates were incorporated into the FORTRAN program (LTWT.FOR) and used to convert age-length and tagging data to weight. The age-weight data (AGEWT.DAT) and tagging data were used to estimate growth parameters only and did not enter directly into the model.

The final step in the data compilation procedure was to combine the catch/effort file (CAEFF.DAT) and the length file (LENGTH.DAT) with the parameters V and V', and the length-weight relationship (Fig. 5). This step was performed with a TURBO-PASCAL program (FISHBIO.PAS). The program used the size distribution to divide the catch into pre-recruits and total recruited components, and the CPUE into newly recruited, recruited and previously exploited components for each of the three qualification methods (Table 7). It calculated the mean lingcod weight, square root of the mean square residual weight, cube root of the mean cube residual weight and fourth root of the mean fourth power residual weight for the recruited, exploited, and total recruited

population components (Table 8). It also calculated the model parameter omega, the proportion of newly recruited fish in the total recruited biomass. An output file with the main fishery and biological data was created for each qualification method (0QUAL.SXD, 25QUAL.SXD, and 02QUAL.SXD) in the format required for model analysis. Additional files were created to include higher order population moments (GROW.SXD) and fishery and biological data in a spreadsheet format (SPREAD.DAT).

Most data files and programs used in the analysis are available to interested users on request on a 360 kilo-byte (main files) diskette. Accessory data files are archived on 1.2 mega-byte diskettes that are not available for distribution. A complete summary of these files with record structures and formats is given in Appendix A and Appendix B, respectively.

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Table 1. Data sources used for constructing the Area 3C lingcod catch series. Algebraic expressions describe the derivation of calculated entries.

Year	U.S. trawl			Can. 3C-N		Trawl	Total	Total
	3C-S	3C-N	3C	Trawl	Line	3C	3C	3C-N
1956-62	?	?	c-b	b	a	c	a+c	?
1963-80	d	c-b-d	c-b	b	a	c	a+c	a+c-d
1981-86	d	0	d	b	a	b+d	a+b+d	a+b

0. No catch.
?. No data source available.
a. British Columbia catch statistics, Annual Reports (with adjustments for weight category).
b. Groundfish data base.
c. Pacific Marine Fisheries Commission, Annual Reports.
d. Washington Department of Fisheries Progress Reports.

Table 2. GFSEL command files used to access the total Canadian trawl catch and the 0%, 25%, and Option-2[a] qualified catch and effort series, respectively, from the Groundfish data base.

GFSEL.COM	GFSEL0.COM	GFSEL25.COM	GOPT2.COM[a]
$GFSEL	$GFSEL	$GFSEL	$GFSEL
SO	SO	SO	SO
1,2	1	1	1
YR	YR	YR	YR
56:86	56:86	56:86	56
MA	MO	MO	MO
3	MAY01-SEP30	MAY01-SEP30	MAY01-JUN30
BOAT_ID	MA	MA	DEPTH
"PASSWORD"	3	3	10,19
ALL	BOAT_ID	TRAWL_GEAR	MI
SP	"PASSWORD"	2,3	Y
467	ALL	BOAT_ID	23
N	TRAWL_GEAR	"PASSWORD"	3,4,5,6,7
N	2,3	ALL	TRAWL_GEAR
SAVE	SP	SP	BOAT_ID
RCANTRT.DAT	467	467	A B C "PASSWORD"
	N	Y	ALL
	1,2,3,4,5,7	25	SP
	SAVE	1,2,3,4,5,7	467
	RTR0.DAT	SAVE	N
		RTR25.DAT	Y
			1,2,3,4,5,7
			SAVE
			RTR02.DAT

a For the Option-2 method several runs were performed to loop through each 10-fa depth interval [loop C, (10,19) to (100, 109)] for each time period [loop B (May01-Jun30), (Jul01-Sep30)] and year [loop A, (56) to (86)]. The two depth intervals with the highest lingcod catch in each period were selected in a second series of runs to produce RTR02.DAT

Table 3. Depth intervals (fa) on the Big Bank fishing ground from which lingcod catch and effort were selected by the Option-2 qualification method for May-June and July-September, 1956-86.

Year	May-June		July-September	
	Range 1	Range 2	Range 1	Range 2
56	40-49			
57	30-39		40-49	30-39
58	30-39		40-49	30-39
59	30-39		30-39	40-49
60	40-49	30-39	50-59	30-39
61	40-49	50-59	50-59	40-49
62	40-49		40-49	50-59
63	40-49	30-39	40-49	30-39
64	30-39		30-39	40-49
65	30-39	40-49	40-49	30-39
66	30-39	40-49	40-49	30-39
67	30-39	40-49	30-39	40-49
68	30-39	50-59	40-49	60-69
69	40-49	60-69	40-49	30-39
70	40-49	50-59	30-39	40-49
71	40-49	30-39	30-39	40-49
72	50-59	40-49	40-49	30-39
73	50-59	40-49	30-39	40-49
74	40-49	30-39	30-39	40-49
75	40-49	50-59	40-49	30-39
76	40-49	50-59	40-49	30-39
77	50-59	40-49	40-49	50-59
78	50-59	40-49	40-49	30-39
79	40-49	30-39	40-49	30-39
80	40-49	50-59	40-49	30-39
81	40-49	30-39	40-49	30-39
82	50-59	30-39	30-39	40-49
83	40-49	50-59	40-49	30-39
84	40-49	50-59	30-39	40-49
85	40-49	50-59	40-49	30-39
86	40-49	30-39	30-39	40-49

Table 4. Number of lingcod sampled by processing stage from Area 3C-N, May-September 1956-86. Processing stages are fork length whole fish FL-W, dressed length DL, and fork length filleted fish FL-F.

Year	No. of samples	No. of Fish			
		FL-W	DL	FL-F	Total
56	1	168		-	168
57	11	-	1351	538	1889
58	9	-	1268	-	1268
59	9	-	1493	-	1493
60	5	-	1455	-	1455
61	16	123	3325	-	3448
62	10	-	2687	-	2687
63	4	-	1095	-	1095
64	10	-	2073	193	2266
65	17	-	3606	-	3606
66	16	845	2715	-	3560
67	10	-	2229	-	2229
68	6	160	607	-	767
69	15	-	2684	-	2684
70	10	-	1667	-	1667
71	9	-	1491	-	1491
72	5	118	454	-	572
73	10	-	1682	-	1682
74	12	156	1513	-	1669
75	3	347	248	-	595
76	7	860	-	-	860
77	1	260	-	-	260
78	-	-	-	-	-
79	1	285	-	-	285
80	2	587	-	-	587
81	2	437	-	-	437
82	2	450	-	-	450
83	1	270	-	-	270
84	3	675	-	-	675
85	5	1214	-	-	1214
86	2	392	-	-	392

Table 5. Number of age determinations used to calculate growth parameters for lingcod from Area 3C-N, May-September 1977-85.

Year	No. of samples	No. of fish
77	1	260
78	2	315
79	1	265
80	2	587
81	1	242
82	2	450
83	1	270
84	2	428
85	2	400
Total	13	3017

Table 6. Interviewed trawl catch (t) and effort (h) for the 0%, 25% and option-2 qualification methods, and Area 3C-N lingcod catch by Canadian and United States trawl, Canadian line, and total catch.

Year	0%		25%		Option-2		Can.-U.S.	Can.	Total
	Catch	Effort	Catch	Effort	Catch	Effort	Trawl	Line	Catch
56	19	105	10	32	5	19	1151	156	1307
57	89	496	71	229	84	404	1070	295	1365
58	154	427	144	309	144	352	1047	156	1203
59	116	494	103	237	91	275	1742	113	1855
60	118	498	103	328	60	178	1867	219	2086
61	330	826	282	610	114	260	1972	136	2108
62	139	835	121	398	27	289	890	228	1118
63	166	885	146	310	40	226	609	147	756
64	292	998	262	583	26	70	1127	101	1228
65	455	1524	424	981	127	500	1812	122	1934
66	481	1960	435	1232	250	795	2030	158	2188
67	689	2039	658	1533	297	642	1779	246	2025
68	461	843	456	700	330	480	1661	156	1817
69	452	1552	437	1311	391	1183	1054	171	1225
70	491	2147	469	1565	390	1112	703	286	989
71	631	3156	549	1573	183	1267	979	231	1210
72	440	3806	265	933	270	1917	625	267	892
73	472	1716	434	1161	370	1153	876	185	1061
74	620	2902	529	2081	540	2166	1029	224	1253
75	1011	3601	955	2874	800	2287	1630	216	1846
76	540	3369	457	2180	428	2097	1205	253	1458
77	441	3650	363	1509	241	1410	844	267	1111
78	237	2218	185	984	202	1213	360	91	451
79	354	2251	323	1440	274	1336	602	82	684
80	321	2217	271	1082	267	1236	623	97	720
81	358	2440	321	1475	225	897	603	240	843
82	1144	3773	1101	3129	753	2017	1510	221	1731
83	525	1923	507	1560	357	1040	970	170	1140
84	925	2675	904	2229	664	1316	1731	128	1859
85	1822	3914	1811	3682	1521	2975	3416	207	3623
86	435	1820	388	1125	231	614	836	241	1077

Table 7. CPUE (t/h) for newly recruited (NR) and previously exploited (PE) population components for the 0%, 25%, and option-2 qualification methods, and catch (10^3t) for pre-recruited (PR) and total recruited (TR) population components for Area 3C-N lingcod, based on V=2.25 kg and V'=2.88 kg.

	0%		25%		Option-2		Catch	
Year	NR	PE	NR	PE	NR	PE	PR	TR
56	0.03704	0.13665	0.06224	0.22963	0.05110	0.18854	0.02348	1.28352
57	0.00987	0.16685	0.01714	0.28968	0.01150	0.19445	0.01332	1.35168
58	0.05178	0.29090	0.06684	0.37554	0.05881	0.33043	0.06175	1.14125
59	0.03678	0.18472	0.06780	0.34052	0.05183	0.26032	0.11332	1.74168
60	0.05614	0.16518	0.07438	0.21884	0.07929	0.23328	0.14069	1.94531
61	0.06199	0.30542	0.07186	0.35409	0.06830	0.33654	0.16767	1.94033
62	0.01154	0.14787	0.02104	0.26960	0.00657	0.08416	0.04973	1.06827
63	0.01035	0.17401	0.02591	0.43581	0.00976	0.16408	0.01374	0.74226
64	0.02859	0.25643	0.04382	0.39308	0.03601	0.32305	0.03200	1.19600
65	0.05486	0.22018	0.07936	0.31849	0.04685	0.18802	0.15317	1.78083
66	0.04259	0.18589	0.06142	0.26803	0.05454	0.23804	0.14907	2.03893
67	0.03876	0.28241	0.04927	0.35898	0.05300	0.38614	0.09956	1.92544
68	0.06714	0.42229	0.08006	0.50352	0.08436	0.53059	0.19140	1.62560
69	0.07791	0.18204	0.08925	0.20855	0.08853	0.20686	0.13124	1.09376
70	0.02564	0.19663	0.03357	0.25746	0.03928	0.30126	0.02813	0.96087
71	0.00541	0.19298	0.00945	0.33672	0.00391	0.13929	0.00914	1.20086
72	0.00362	0.10920	0.00891	0.26860	0.00442	0.13324	0.02080	0.87120
73	0.01245	0.25490	0.01693	0.34685	0.01454	0.29776	0.02938	1.03162
74	0.02555	0.17628	0.03040	0.20974	0.02987	0.20604	0.06843	1.18457
75	0.03796	0.20868	0.04492	0.24696	0.04729	0.26000	0.22467	1.62133
76	0.00489	0.15140	0.00640	0.19787	0.00623	0.19284	0.03704	1.42096
77	0.00458	0.10811	0.00960	0.22688	0.00683	0.16141	0.01892	1.09208
78	0.00527	0.09940	0.00927	0.17469	0.00824	0.15531	0.00880	0.44220
79	0.00927	0.14467	0.01324	0.20652	0.01207	0.18831	0.01504	0.66896
80	0.00856	0.13101	0.01482	0.22688	0.01280	0.19592	0.02486	0.69514
81	0.01301	0.10781	0.01929	0.15995	0.02226	0.18456	0.14925	0.69375
82	0.03777	0.24729	0.04386	0.28713	0.04651	0.30445	0.10336	1.62764
83	0.02795	0.23581	0.03332	0.28110	0.03515	0.29652	0.03740	1.10260
84	0.02631	0.30723	0.03088	0.36055	0.03837	0.44811	0.06607	1.79293
85	0.01781	0.42580	0.01882	0.44996	0.01955	0.46745	0.17071	3.45229
86	0.02296	0.20293	0.03305	0.29217	0.03602	0.31837	0.06001	1.01699

Table 8. Mean weight (kg), square root of the mean square residual weight (R#2), cube root of the mean cube residual weight (R#3) and fourth root of the mean fourth power residual weight (R#4) for the newly recruited, previously exploited and total recruited population components for Area 3C-W Iingood, based on V=2.25 kg and V'=2.88 kg.

Year	Newly Recruited				Previously Exploited				Total Recruited			
	Mean	R#2	R#3	R#4	Mean	R#2	R#3	R#4	Mean	R#2	R#3	R#4
56	2.67738	0.14498	-0.1352	0.18971	3.88392	1.01265	1.3055	1.73479	3.54342	1.01827	1.2962	1.75034
57	2.63428	0.18031	-0.1273	0.20698	4.74279	1.92254	2.6675	3.56704	4.53981	1.93139	2.6453	3.56984
58	2.59163	0.17976	0.0631	0.20483	4.85335	1.96923	2.7140	3.69483	4.28792	1.96866	2.659	3.67071
59	2.60122	0.18558	-0.0717	0.20897	4.91478	2.07382	2.5218	3.39998	4.28238	2.04883	2.5417	3.41834
60	2.60190	0.18557	-0.0772	0.20908	4.32663	1.75412	2.4905	3.38424	3.70384	1.63236	2.3617	3.26535
61	2.61326	0.17977	-0.0964	0.20566	4.59253	2.03304	2.7719	3.67174	4.07217	1.95301	2.701	3.62644
62	2.57173	0.17872	0.0959	0.20494	5.86694	2.51192	2.7769	3.79069	5.36893	2.59885	2.8412	3.89001
63	2.60717	0.18084	-0.0709	0.20520	5.42213	1.83566	1.8891	2.69226	5.11235	1.94383	1.9180	2.78773
64	2.62342	0.17269	-0.1034	0.20109	4.68548	1.58461	2.0360	2.92809	4.34308	1.63946	2.0290	2.93266
65	2.59557	0.17788	-0.0346	0.20355	4.86868	2.05867	2.7053	3.70822	4.14464	2.00495	2.6587	3.65870
66	2.59489	0.18428	-0.0881	0.20980	4.56154	1.96431	2.7141	3.63460	3.99684	1.88468	2.6308	3.57397
67	2.62552	0.18159	-0.1083	0.20654	4.59590	1.58048	2.1679	3.02058	4.21419	1.62074	2.1370	3.01628
68	2.56988	0.17099	0.0415	0.19858	5.25664	2.10052	2.5404	3.46302	4.59729	2.16179	2.5756	3.52449
69	2.60070	0.17833	-0.0515	0.20364	4.69453	2.48848	3.3078	4.34821	3.78196	2.14136	3.0949	4.14441
70	2.61539	0.17739	-0.0904	0.20311	5.13969	2.48120	3.1017	4.03170	4.62479	2.43755	3.0982	4.05576
71	2.63972	0.18775	-0.1145	0.20819	5.58988	2.40457	2.9576	3.86745	5.42441	2.43319	2.9589	3.90148
72	2.60158	0.18586	-0.1154	0.21324	6.76644	2.36369	2.4910	3.55327	6.43577	2.53260	2.4584	3.69478
73	2.61174	0.17834	-0.0964	0.20462	7.45935	3.48894	3.3099	4.69042	6.86609	3.63466	3.4635	4.87212
74	2.59254	0.18195	-0.0284	0.20707	5.92361	2.68437	2.9044	3.95240	5.09485	2.73772	3.0485	4.07982
75	2.56384	0.18811	0.0864	0.20912	5.03730	2.76180	3.9057	5.24496	4.38610	2.61063	3.7665	5.12408
76	2.56672	0.16640	-0.0959	0.19739	5.87719	2.77077	3.3575	4.35800	5.64902	2.80236	3.3651	4.40515
77	2.60912	0.18215	-0.1241	0.21306	5.70189	1.99223	2.4587	3.61404	5.44000	2.09215	2.4402	3.64995
78	2.58516	0.18286	-0.0151	0.21063	5.68050	2.04090	2.2204	3.24500	5.35740	2.14967	2.2512	3.32373
79	2.56121	0.18357	0.0940	0.20820	5.65912	2.08957	1.9822	2.87596	5.27479	2.20719	2.0621	2.99750
80	2.58669	0.17789	-0.1077	0.20437	4.73473	1.48405	1.7033	2.28314	4.50529	1.55265	1.7105	2.34942
81	2.51422	0.18031	0.1186	0.20635	5.14166	2.33489	3.1353	4.40640	4.62174	2.33990	3.0990	4.37102
82	2.58175	0.20221	-0.1096	0.22213	5.02020	2.11275	2.5413	3.47809	4.46178	2.12148	2.5702	3.50352
83	2.58590	0.17031	-0.0981	0.20030	5.02597	2.05161	2.5208	3.40631	4.56906	2.08147	2.5351	3.44323
84	2.59740	0.17729	-0.1125	0.20534	5.05521	2.14311	2.7371	3.63373	4.70409	2.16355	2.7322	3.66276
85	2.51236	0.19104	0.1340	0.21915	5.56770	2.20257	2.6765	3.70952	5.30853	2.27323	2.6747	3.75401
86	2.55324	0.18039	0.0658	0.20484	6.10867	2.89049	3.4960	4.73629	5.35130	2.94980	3.5352	4.80748

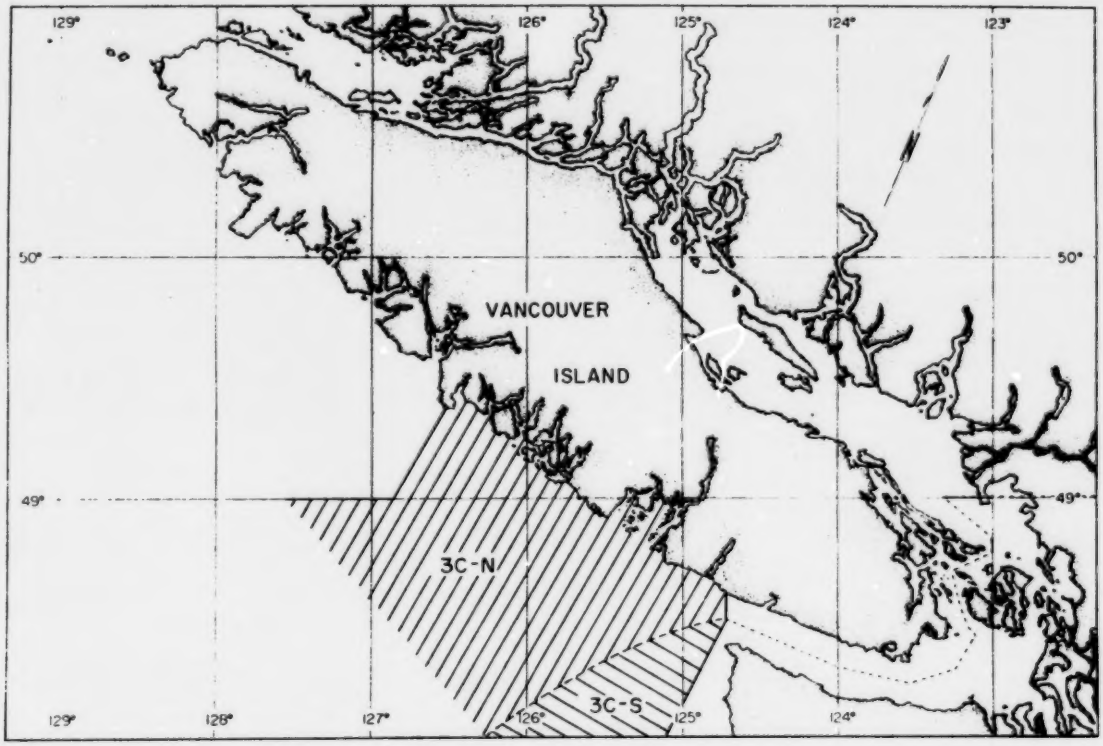

Fig. 1. Pacific Marine Fisheries Commission (PMFC) Major Area 3C showing the Canadian (3C-N) and U.S. (3C-S) portions.

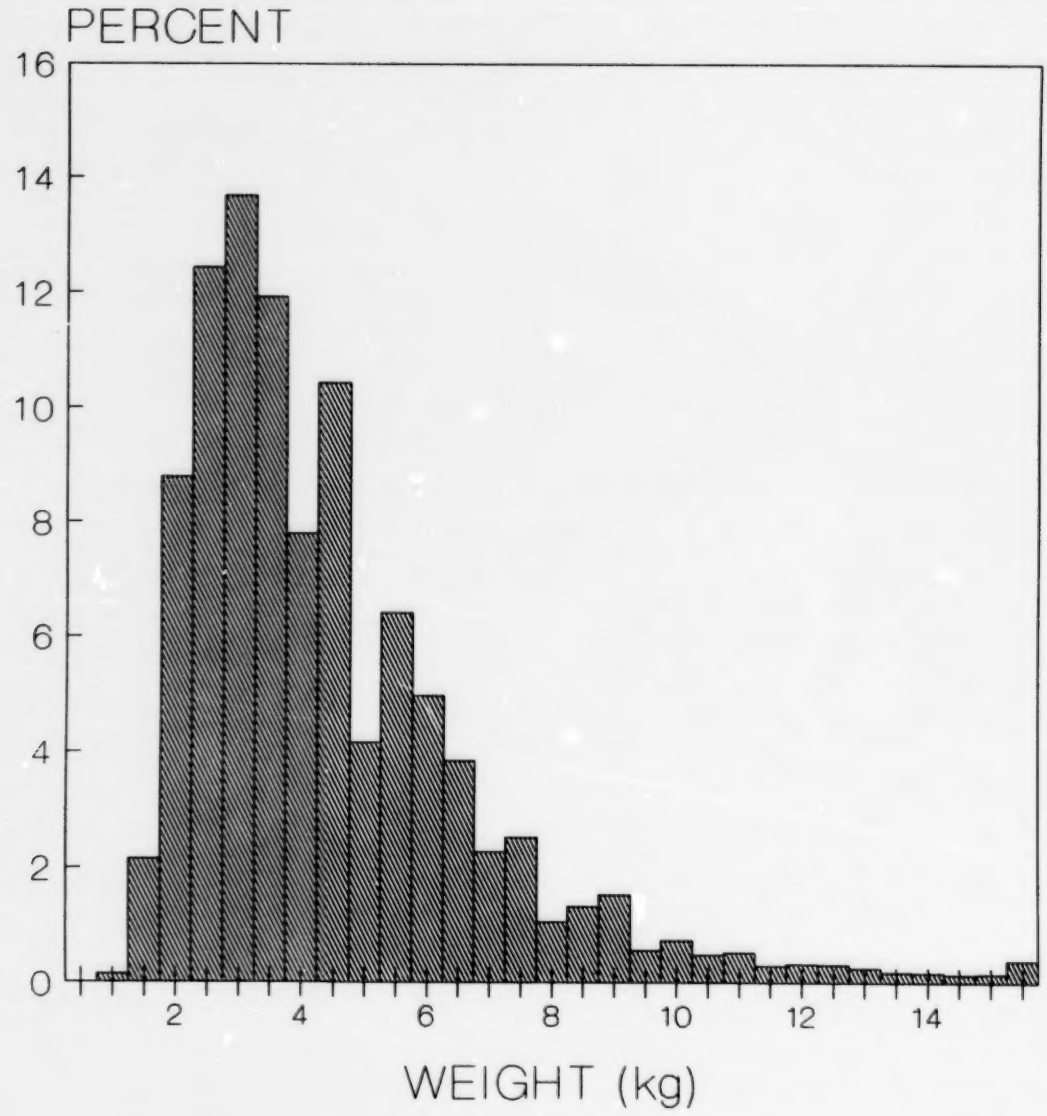

Fig. 2. Percentage of Area 3C-N lingcod by weight category. Weight categories are defined for 0.5 kg intervals, and the percentages are averaged over the period 1956-86. The final category accounts for all fish within the interval centered on 15.5 kg or larger, i.e., all fish larger than 15.25 kg.

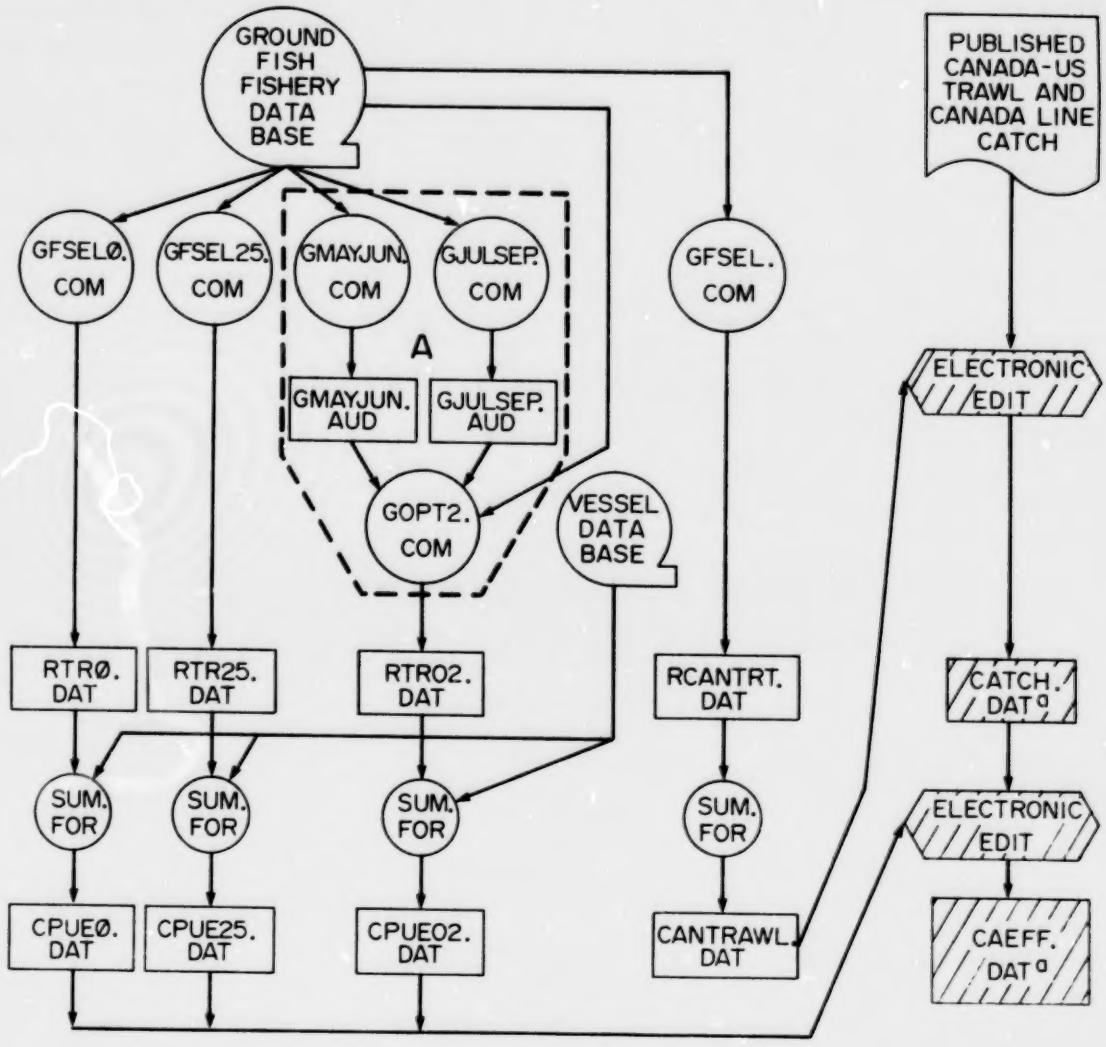

Fig. 3. Flow chart showing the sequence of compilation of fisheries data used in an analysis of Area 3C-N lingcod. Hatched symbols depict compilations on an IBM-compatible personal computer. Unhatched symbols depict compilations on a VAX mainframe computer. Superscript "a" denotes data files and programs located on a 360 kilo-byte diskette and described in Appendix A. All other files are described in Appendix B. Steps in Box A depict the relatively complex process in the selection of data for the Option-2 method. For this method, the command files GMAYJUN.COM and GJULSEP.COM select records by 10-fa intervals for each year and time period (i.e. May-June). The two depth intervals with the largest catches of lingcod in each year and time period (see Table 3) are then used in the command file GOPT2.COM as a selection criteria for a subsequent loop through the Groundfish Data Base.

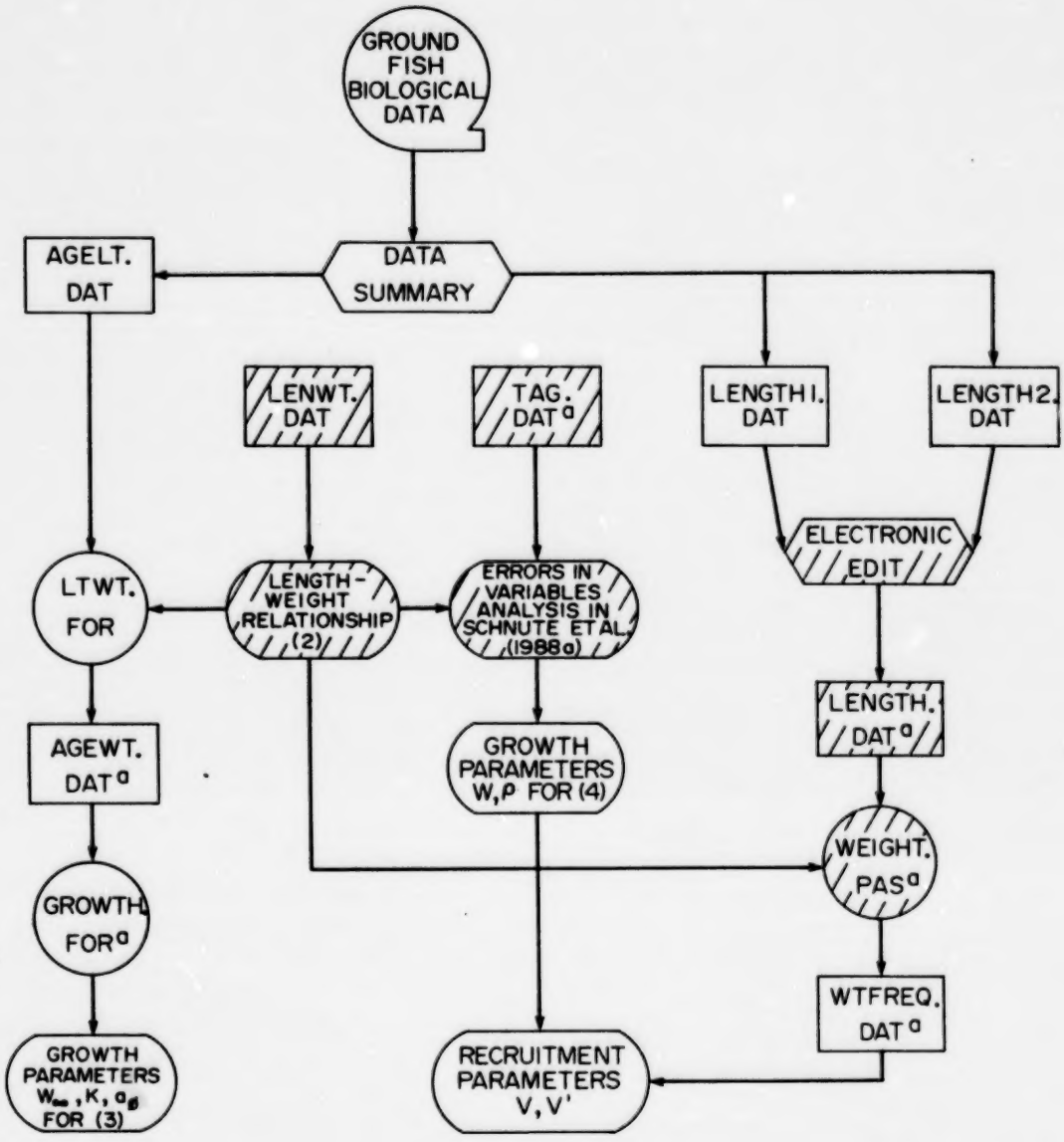

Fig. 4. Flow chart showing the sequence of compilation of biological data used in an analysis of Area 3C-N lingcod. Hatched symbols depict compilations on an IBM-compatible personal computer. Unhatched symbols depict compilations on a VAX mainframe computer. The superscript "a" denotes files and programs located on a 360 kilo-byte diskette and described in Appendix A. All other files are described in Appendix B.

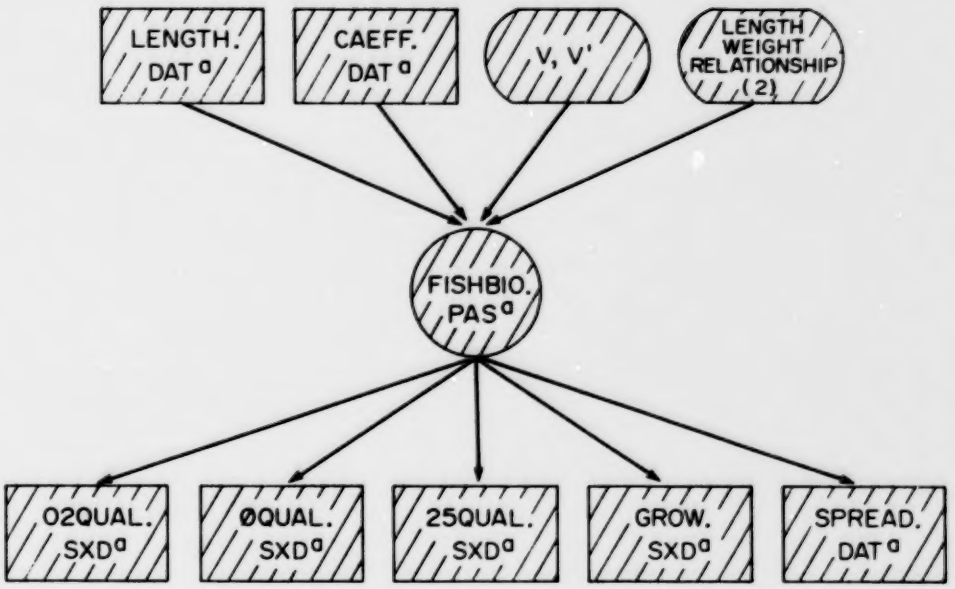

Fig. 5. Flow chart showing the compilation procedure used on an IBM-compatible PC to combine fisheries and biological data used in an analysis of Area 3C-N lingcod. The superscript "a" denotes files and programs located on a 360 kilo-byte diskette and described in Appendix A.

Appendix A. A description of the main data files and programs used in the analysis of Area 3C-N lingcod. These files are available on a 360 kilo-byte diskette.

AGEWT.DAT. Data file of age and weight. Format: age, weight.

CAEFF.DAT. Fishery data file with time-series of 0%, 25% and option-2 catch and effort and total catch. Format: year, 0% qualified catch, 0% qualified effort, 25% qualified catch, 25% qualified effort, option-2 catch, option-2 effort, total catch.

CATCH.DAT. Fishery data file with time-series of total catch by gear type. Format: year, line catch, Canada-U.S. trawl catch, total catch.

LENGTH.DAT. Biological data file of length-frequencies, 1956-77, 1979-86. Format: sample type (1=dressed length, 2=fork length-frames, 0=fork length-whole), year, length (cm), no. of fish.

SPREAD.DAT. Spreadsheet file with time-series of fishery and biological data. Format: year, newly recruited option-2 CPUE, previously exploited option-2 CPUE, recruited option-2 CPUE, total option-2 effort, newly recruited 0% qualified CPUE, previously exploited 0% qualified CPUE, recruited 0% qualified CPUE, total 0% qualified effort, newly recruited 25% qualified CPUE, previously exploited 25% qualified CPUE, recruited 25% qualified CPUE, total 25% qualified effort, recruited catch, pre-recruited catch, newly recruited: mean weight, mean square root residual weight, mean cube root residual weight, mean fourth root residual weight; previously exploited: mean weight, mean square root residual weight, mean cube cube residual weight, mean fourth root residual weight; recruited: mean weight, mean square root residual weight, mean cube root residual weight, mean fourth root residual weight.

TAG.DAT. Data file of 1982 release length and recovery length of tagged lingcod released in Area 3C-N. Format: sex, release length, recovery length.

WTFREQ.DAT. Percent weight frequency distribution for Area 3C-N lingcod by year for the period 1956-86. Weight categories are defined for 0.5 kg intervals. Format: year, no. of fish, percent frequency in 0.5 kg intervals for the weight range 0.75 kg to 15.25 kg.

GROWTH.FOR FORTRAN template used in the simplex search procedure to calculate the growth parameters. Input: AGEWT.DAT.

FISHBIO.PAS. Turbo-Pascal program to merge fishery and biological data in the format used by the model. The program prompts for V' and the weight at recruitment. The program calculates the qualified recruited catch and the newly recruited, recruited and previously exploited CPUE for each of the three methods. The program also calculates the pre-recruited and recruited catch and the newly recruited, previously exploited and recruited population moments and a weight ratio parameter, omega. Input: LENGTH.DAT, CAEFF.DAT. Output: 0QUAL.SXD, 25QUAL.SXD, 02QUAL.SXD, GROW.SXD and SPREAD.DAT.

WEIGHT.PAS. Turbo-Pascal program to create a weight frequency distribution by year for weight categories of 0.5 kg intervals. Input: LENGTH.DAT. Output: WTFREQ.DAT.

0QUAL.SXD. Model input data file with time-series of 0% qualified catch and effort, CPUE, mean weights and weight ratios. Format: year, 0% qualified recruited catch, 0% qualified effort, 0% qualified recruited CPUE, 0% qualified newly recruited CPUE, 0% qualified previously exploited CPUE, recruited catch, total 0% qualified effort,recruited mean weight, newly recruited mean weight, previously exploited mean weight, omega.

25QUAL.SXD. Model input data file with time-series of 25% qualified catch and effort, CPUE, mean weights and weight ratios. Format: year, 25% qualified recruited catch, 25% qualified effort, 25% qualified recruited CPUE, 25% qualified newly recruited CPUE, 25% qualified previously exploited CPUE, recruited catch, total 25% qualified effort, recruited mean weight, newly recruited mean weight, previously exploited mean weight, omega.

02QUAL.SXD. Model input data file with time-series of option-2 catch and effort, CPUE, mean weights and weight ratios. Format: year, option-2 qualified recruited catch, qualified effort, option-2 recruited CPUE, total option-2 effort, recruited catch, recruited mean weight, newly recruited mean weight, previously exploited mean weight, omega.

GROW.SXD. Model input file with time-series of population moments. Format: year, recruited: mean weight, mean square root residual weight, mean cube root residual weight, mean fourth root residual weight; newly recruited: mean weight, mean square root residual weight, mean cube root residual weight, mean fourth root residual weight; previously exploited: mean weight, mean square root residual weight, mean cube root residual weight and mean fourth root residual weight.

Appendix B. A description of accessory data files and programs used in the analysis of Area 3C-N lingcod. These files are archived on 1.2 mega-byte diskettes.

AGELT.DAT. Biological data file of raw length and age data. Format:

Field	Byte
vessel[a]	1-3
date (YYMMDD)	4-9
set no.	10-12
major-minor-locality[a]	13-18
species (lingcod=467)	19-21
fish no.	22-28
length (cm)	45-47
gear	50-51
average depth (m)	52-54
sex	55
maturity	56-57
age rating	58
age (yr)	61-63

a Confidential vessel and locality codes were excluded from data files. Vessel codes were replaced by vessel horsepower class. Locality codes were recorded blank.

CANTRAWL.DAT. Fishery data file with time-series of Canadian lingcod trawl catch. Format: year, catch.

CPUE0.DAT. Fishery data file with time-series of 0% catch and effort. Format: year, 0% catch, 0% effort.

CPUE25.DAT. Fishery data file with time-series of 25% catch and effort. Format: year, 25% catch, 25% effort.

CPUEO2.DAT. Fishery data file with time-series of option-2 catch and effort. Format: year, option-2 catch, option-2 effort.

LENGTH1.DAT. Biological data file of length-frequencies, 1956- 76. Format: sample type (1=dressed length, 2=fork length-frames, 0=fork length-whole), year, length (cm), no. of fish.

LENGTH2.DAT. Biological data file of length-frequencies, 1977, 1979-86. Format: sample type (1=dressed length, 2=fork length-frames, 0=fork length-whole), year, length (cm), no. of fish.

LENWT.DAT. File of length and weight data used to estimate the length-weight relationship. Format: sex, length, weight.

RTR0.DAT. 0% qualified raw trawl catch and effort data. Format: (for specific codes see Leaman and Hamer 1985).

Field	Byte
source	1
serial	2-5
year	10-11
port	12
vessel[a]	13-15
Class-gear-aid	16-18
trip length	19-20
major-minor-locality[a]	21-24
days fished	27-30
no. of sets	31-32
time (min)	33-37
depth (fa)(min,max,avg)	47-50
no. of species	62-63
total catch	64-70
species records:	
species code (lingcod=467)	1-3
utilization	4
catch (lb)	5-11

a Confidential vessel and locality codes were excluded from data files. Vessel codes were replaced by vessel horsepower class. Locality codes were recorded blank.

RTR25.DAT. 25% qualified raw trawl catch and effort data. Format (see RTR0.DAT).

RTR02.DAT. Option-2 raw trawl catch and effort data. Format (see RTR0.DAT).

RCANTRT.DAT. Canadian raw trawl catch data. Format (see RTR0.DAT).

GFSEL.COM. GFSEL command file for selecting total Canadian trawl catch. Input: Groundfish data base. Output: RCANTRT.DAT.

GFSEL0.COM. GFSEL command file for selecting 0% qualified catch and effort. Input: Groundfish data base. Output: RTR0.DAT.

GFSEL25.COM. GFSEL command file for selecting 25% qualified catch and effort. Input: Groundfish data base. Output: RTR25.DAT.

GOPT2.COM. GFSEL command file for selecting option-2 catch and effort. Input: Groundfish data base. Output: RTR02.DAT.

GMAYJUN.COM. GFSEL command file for selecting catch by 10 fa depth interval for May-June 1956-86. Input: Groundfish data base. Output: GMAYJUN.AUD.

GJULSEP.COM. GFSEL command file for selecting catch by 10 fa depth interval for July-September 1956-86. Input: Groundfish data base. Output: GJULSEP.AUD.

GMAYJUN.AUD. Report file from GFSEL with catch by 10 fa depth interval for May-June 1956-86.

GJULSEP.AUD. Report file from GFSEL with catch by 10 fa depth interval for July-September 1956-86.

LIWT.FOR. FORTRAN program to perform the length-weight conversions on raw age-length data. Input: AGELT.DAT. Output: AGEWT.DAT.

SUM.FOR. FORTRAN program to standardize for vessel horsepower class and summarize catch and effort data. The program prompts for a raw catch or catch and effort file from GFSEL. Input: RTR0.DAT, RTR25.DAT, RTR02.DAT, or RCANTRT.DAT, and Groundfish vessel data base. Output: CPUE0.DAT, CPUE25.DAT, CPUE02.DAT, or CANTRAWL.DAT. SUM.FOR was modified to read vessel horsepower class directly from raw data files in order to bypass confidential vessel codes and the Groundfish vessel data base.